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Connecting Customers with Engineers for the Successful Fuzzy Front End: Requirements of Tools

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Connecting Customers with Engineers for the Successful Fuzzy Front End: Requirements of Tools

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Abstract--**In technology-driven enterprises, marketing typically acts as a "go-between" that captures customer needs and experiences and aggregates and interprets them for engineering. Knowledge exchange thus occurs through an indirect path. However, as a result of rapidly changing and unpredictable environments and complex products with tacit requirements, companies increasingly emphasize the need for engineering to be more strongly engaged with customers'. Accordingly, an increasing number of methods for customer research in early stages on new product development, the so-called fuzzy front end (FFE), emphasize direct knowledge exchange and collaboration between engineering and customers.**

Based on a review of the literature, this paper establishes six requirements for such methods from the perspective of engineering: information processing, simulation of scenario, reflection of dynamic customer knowledge change, interactive communication, exchange of subjective interpretation and drawing organizational interpretation. Subsequently ten tools which are typically applied for customer involvement activities and capturing customer knowledge in the FFE are evaluated according to the requirements. As a result, simulation of scenario is hardly dealt with by any methodologies. In addition, some methodologies require additional help or education for engineers and have difficulties with being diffused throughout general fields from specific industries.

I. INTRODUCTION

Globalization and advanced communication systems have enabled firms to get resources, including information, more easily and cost effectively and to pioneer larger markets all across the world. Customers can access information on countless products online, are able to communicate about these products with others through the internet, and can become more actively involved in new product development (NPD) than ever before. However, despite these new means for communication, the new product failure rate has remained unchanged for several decade and is still 30% to 80% percent [1]. More complex and faster-changing technologies may have actually increased the difficulty of developing winning products, and for some new technologies, such as the Internet of things (IoTs), service robotics and mobile telecommunication, the forecasting of future customer needs or desires remains particularly challenging [2]. Gathering relevant customer knowledge in the front end of new product development to enable solid strategies therefore remains a challenge. The ability to acquire and build future customer needs in product development organizations affects financial NPD performance and innovativeness [3].

To capture customer knowledge in technology-driven enterprises, researchers and practitioners have suggested and tested a multitude of methodologies. NPD teams typically capture customer needs and experience at points of regular customer interaction from service and sales divisions, or through researches by marketing professionals. Then, they convey their insights to product development engineers after analyzing the information. However, for successful NPD in the rapidly changing and unpredictable environment of technology-driven industries, engineers may need to access customers' knowledge on needs and experiences more directly and in more detail. Accordingly, engineering is encouraged to collaborate more frequently with customers than ever before, particularly in early stages of the new product development process (NPD) [4]–[6]. In addition, customers are now more likely to be actively involved in NPD, which enables firms to create unique value for products [7]. Also, cooperation with external stakeholders enables NPD teams to get access to knowledge, skill, markets and distribution channels; to enhance compatibility; to speed up the product development process; and to reduce product development risks and investments [8]. Nevertheless, engineers as core members of new product development teams are still struggling with accessing customer knowledge [6], [9], resulting in misunderstandings and conflicts with other divisions, such as marketing. This paper argues that current customer research methods puts too little emphasis on communicating insights to engineering teams. Based on the literature, it develops the requirements for such methods from the perspective of engineering. For this purpose, three research questions are developed below:

- What are the distinctive characteristics of the fuzzy front end (FFE) that influence how engineers understand customer knowledge?
- What are the requirements for tools that capture customer needs in order to create customer value in the FFE of technology-driven industry?
- What methodologies are applicable to capture customer needs and create customer values in the FFE?

To find answers for these questions, the next chapter describes the definition and the main characteristics of the FFE.

II. FUZZY FRONT END

According to Brentani and Reid [10], the FFE can be defined as the earliest stage of the NPD process. Similarly, Schoonmarker et al. define the FFE as a pre-development process between R&D and the beginning of formal NPD process [11]. This pre-development process consists of

several subordinate activities, namely ideation, initial assessment, concept development and business case analysis [12]. However, there is no distinctive boundary between each activity, and each activity is interrelated with others [13], [14]. Accordingly, there is no single best way for a product idea to pass through the front-end and Khurana and Rosenthal advised that, when managing the FFE, firms need to consider various options according to their size, decision-making style, operating culture and new product introduction frequency [13]. Given the interrelatedness of FFE activities, which leads to iterations, Koen et al. argue that management approaches that rely on a sequential process are inappropriate for FFE management [15]. Instead, they propose a new model, the so called new concept development (NCD) model, to provide a common language and insight into the FFE [16]. Models similar to the NCD model have since been proposed by other researchers [12].

Since Smith and Reinertsen [17] first introduced the term, the FFE has received growing attention by researchers and practitioners, who regard the FFE to be a crucial part of the whole NPD process for successful product launching [18]. In this regard, researchers and practitioners testified that the early process of NPD involves the greatest opportunities for improvement of the whole innovation process [19]–[21]. Additionally, the FFE strongly impacts the success of new product development such as performance, cycle time or speed of NPD process and innovativeness [10], [22], [23]. Nevertheless, firms tend to still devote limited effort to the FFE , unlike other NPD stages [13], and hesitate to input resources and investments for the FFE because of the high uncertainty and resulting risk of such investments [18], [24], [25].

The most frequently discussed characteristic of the FEE is uncertainty. According to Kim and Wilemon, various uncertainties coming from technologies, markets, resources and capabilities of firms prevent an opportunity from reaching the regular development process [18]. Also, Schröder and Jetter categorized uncertainties of the FFE into four types: market uncertainty, technological uncertainty, environmental uncertainty and uncertainty about resource allocation, and Figure 1 shows causes of each uncertainty [26]. Above all things, lack of information is the main cause of uncertainty.

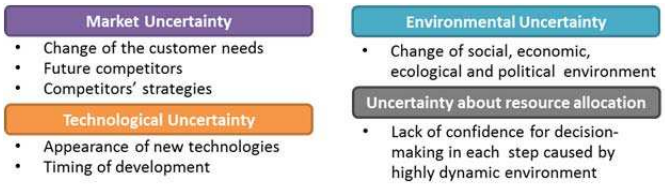

Figure 1. Causes of Uncertainty

These uncertainties lead to poor product concepts, wrong target market and misallocation of resources through whole development process, and, consequently, cause product failure. Thus, several researchers have suggested processes and methodologies to reduce uncertainties or to manage their impacts. For example, Kim and Wilemon [27] recommend a holistic FFE process that is heavy on customer involvement. Their recommended approach to the FFE also nurtures multiple fuzzy ideas, rather than selecting single solutions too early under high uncertainty [27]. And, Sperry and Jetter showed a framework to select an appropriate FFE process according to characteristics of an innovation project [12].

A second characteristic of the FFE that impedes product success is equivocality. Equivocality is defined as a difficulty in knowledge exchange or consensus on issues that members of a NPD team face due to subjective and conflicting interpretation by each individual [25], [28]. Consequently, equivocality is the main cause of communicational difficulties and conflicts within multidisciplinary NPD teams or organizations [25], [28], [29]. In particular, a number of researches have reported conflicts between marketing and R&D in NPD teams [6], [30]–[34]. For instance, according to Shaw and Shaw, the main sources of conflict between engineers and marketers are poor communications and lack of understanding each other [6]. While marketers tend to focus on matching customer preferences, engineers usually concern feasibilities and effectiveness of technologies in NPD projects [35]. This subjective difference also appears between developers and customers [36]. Despite of these subjective differences among project participants including customers, equivocality in the FFE has been studied less and received less attention than uncertainty because the effects of both uncertainty and equivocality may combine to impact the performance of the FFE activities.

Recently, many firms involve customers actively in the early stages in NPD projects in a variety of forms., One of the methods used to involve customers is the employment of the "Lead User" technique, which was pioneered by Von Hippel [37]–[39]. Also, some NPD teams, especially in the information technology industry, need to collaborate directly with customers. In this collaboration, agile product development is helpful in enabling the NPD teams to provide solutions to customers rapidly by sharing common goals [40]. As a result, engineers have had more chances to contact with customers directly for a decade.

However, customer involvement in the early stages of NPD does not always guarantee effective communication between NPD teams and customers. Though early customer involvement can be helpful in reducing uncertainty, subjective divergence of interpretation between engineers and customer may nevertheless result in equivocality To resolve equivocality, researchers and practitioners have recommended having face-to-face meeting as frequent as possible, or using integrators who are in charge of delivering an agreement among various stakeholders who have different understanding or interests from each other [28], [41]. However the Nonetheless, like uncertainty of the FFE, some systemic approaches are required to solve issues caused by equivocality.

As mentioned above, the performance of the FFE is affected by unclear information and different subjective interpretations. Though there have been suggestions and recommendations to moderate difficulties or obstacles for the successful FFE, customer involvement is one of the more effective solutions to resolve uncertainty and equivocality. In this regard, efficient communication, or knowledge flow, between engineers and other NPD teams or between engineers and customers is critical for the customer involvement. Therefore, the next chapter develops a framework for communication with customers in the FFE.

III. FRAMEWORK: COMMUNICATION WITH CUSTOMERS

The process of communication, through which a message from a sender reaches a receiver, requires six elements; source, encoder, message, channel, decoder and receiver [42]. During this process, the original meaning of the message may be distorted by interference of internal and external factors, whereupon the receiver may interpret the message differently. Internal factors of distortion, such as communication skills, attributes, knowledge level and position within social-culture system, affect the sender when expressing an idea in language. They also affect the receiver in understanding the language sent by the sender [43]–[45]. In addition, external distortion factors, such as language difference, illegible print and background noise, may obstruct communication between the sender and the receiver [46]. Figure 2 depicts the communication process mentioned above: the lightning bolts indicate disturbances at each process step, which can lead to equivocality among people or organizations.

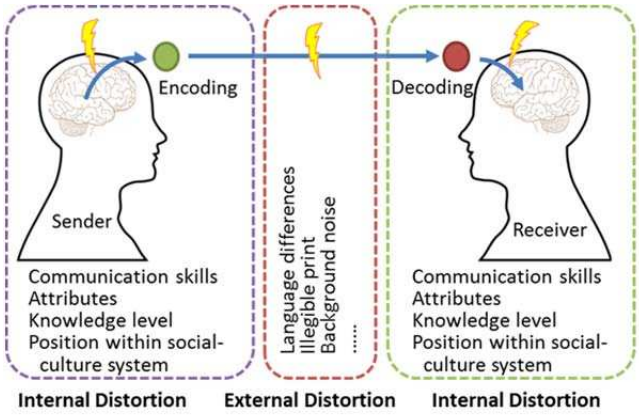

Figure 2. Communication Process

In the context of product development, distortions can limit effective communication between engineers and customers who are involved in the FFE. Figure 3 reveals the path of knowledge flow between engineers and customers. In the Figure 3, the lightning bolts also mean disturbance on each knowledge flow. First, when marketers act as intermediators in typical knowledge flow between engineers and customers, the interpretation of marketers may affect the quality of communication because marketers generally have backgrounds and experiences that are different from ones of engineers [9]. Table 1 shows the different orientation between R&D people and marketing people [47]. If marketers are influenced by some internal or external factors in the process of capturing customer idea or sending the result to engineers, the engineers may receive distorted information by marketers' interpretation and vice versa. In this case, it is possible that engineers may bring inappropriate technologies as the solution on the customer needs, or establish an insufficient technological specification for the product.

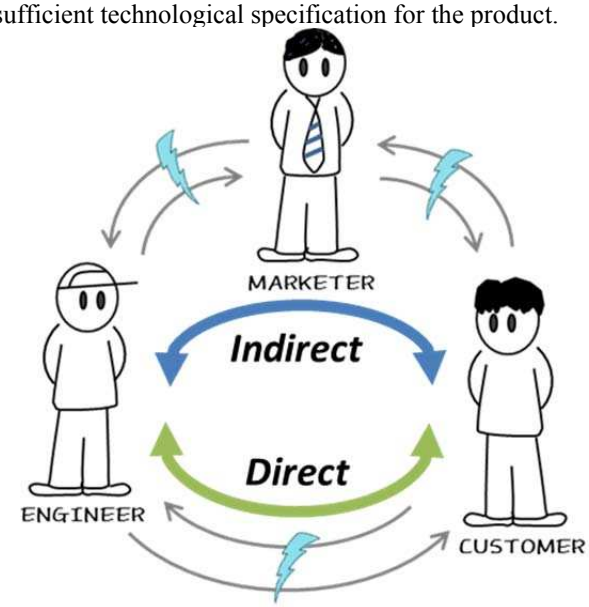

Figure 3. The path of knowledge flow between engineers and customers

TABLE 1. DIFFERENT ORIENTATION BETWEEN R&D AND MARKETING [48]

	R&D	Marketing
Time Orientation	Long	Short
Projects Preferred	Breakthrough	Incremental
Ambiguity Tolerance	Low	High
Department Structure	Informal	Moderately formal
Bureaucratic Orientation	Less	More
Orientation to others	Permissive	Permissive
Professional Loyalty	Profession	Firm
Professional Orientation	Science	Market

On the other hand, engineers are now required to communicate directly with customers through various ways in the FFE under "Open Innovation" era [49]. In other words, in some industries such as software and IT, engineers contact customers directly from the early stage of development process without intermediators [40]. In this circumstance, engineers need to interpret customer needs obtained by direct contacts with customers to technological languages such as technological terms or numerical values. However, extracting customer knowledge is not easy work. According to several researches, customers have limitation to articulate their knowledge [50]–[55]. While they have no difficulties in presenting their needs or problems which they have already

experienced or are familiar with, they have troubles in showing their latent or unfamiliar knowledge [55]. Additionally, according to Riquelme, even their memory on the products they experienced is unstable, and so they often provide unclear information to their count partners [50].

Therefore, engineers need special education or systematic approaches for getting access to customer knowledge directly or indirectly. Also, firms need other new approaches with which they help customers to present their knowledge efficiently and clearly for a NPD project, and which they interact with customers frequently and vibrantly.

Considering these conditions, next chapter describes the brief explanation and limitations of each typical methodology in connecting engineers to customer knowledge.

IV. METHODOLOGIES FOR FACILITATING COMMUNICATION

Figure 4 shows how typical methodologies connect engineers to customers in the FFE. In exchanging knowledge between customers and engineers, there are three types of knowledge paths; serial, parallel and direct. Also, according to Fiona, methodologies to acquire customer knowledge are categorized into needs-focused methodologies which focus on looking for current and latent need of customers and solution focused ones which concentrate on finding creative input and technological expertise [56]. Table 2 also explains each methodology and related references in each type of knowledge path.

A. Serial Type of Knowledge Path

First, in the serial type of knowledge path, marketers have an important role in delivering knowledge between engineers and customers. Classically, marketers conduct market researches to acquire customer knowledge with various methodologies, such as concept test, interview, focus group, conjoint analysis, and ethnography. The results of these market researches should ensure precise and abundant information from customers, so that following activities within development teams can seek better solutions based on the market research results. With the results from market research activities acquiring customer knowledge, development teams look for the optimal technological solutions and alternatives for product concepts. For this activity, engineers collaborate heavily with members from other divisions such as manufacturing, quality control, sales as well as marketing. At this time, it is important to communicate with each other systematically and harmoniously without conflicts. For systematic and harmonious collaboration, several methodologies, such as quality function deployment (QFD), analytical target cascading (ATC), internal brainstorming and TRIZ, have been proposed and applied in the FFE [5], [9], [15], [20], [57], [58].

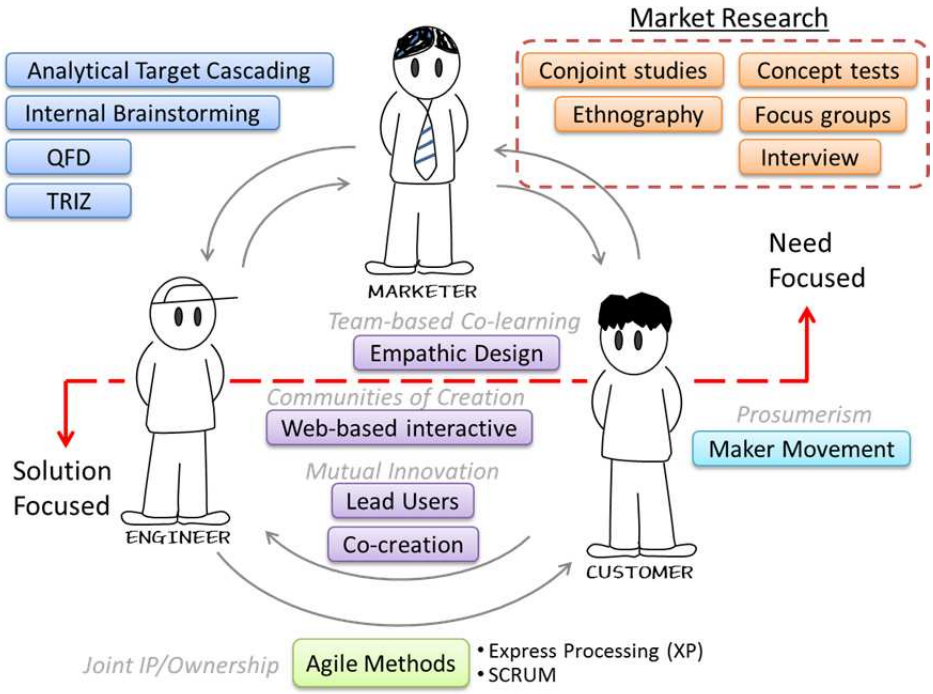

Figure 4. Typical Methodologies for Customer Involvement in the FFE

TABLE 2. METHODOLOGIES FOR COMMUNICATION BETWEEN ENGINEERS AND CUSTOMERS

Knowledge Path Type	Methodologies		References
Serial Type (Marketers deliver customer knowledge to engineers.)	Analytical Target Cascading (ATC)	A system optimization methodology by using a hierarchy composed of subsystems modeled mathematically Optimizing product spec. with engineering design and marketing product planning by conjoint analysis	Michalek et al. [9]
	Quality Function Deployment (QFD)	A development process to convert qualitative customer knowledge to quantitative design parameters in order to achieve customer satisfaction on a target product	Griffin & Hauser [5]; Schmidt [57]
	TRIZ	A methodology for problem solving and idea generation by identifying conflicts in problem, and then conducting analysis and solutions	Koen [15] ; Ulrich & Eppinger [58]
	Internal Brainstorming	A collective communication methodology for idea generation to draw the results of market research from marketers and technological solution idea from engineers	Lovelace et al. [59] ; Ulrich & Eppinger [58]
Parallel Type (Engineers and Marketers are connected to customer knowledge in parallel.)	Empathic Design	A user-centered design approach to extract customers' unarticulated needs by observing users' world with empathy.	Leonard & Rayport [60]
	Web-based interactive	Based on the Internet, virtual customer communities enable firms to facilitate the communication and collaboration over all of NPD process.	Büyüközkan et al. [61]; Nambisan [62]
	Lead Users	An collaboration methodology to sense a leading-edge market trend and innovative solution by collecting knowledge from users who have "lead user" characteristics	Von Hippel [4]; Von Hippel [63]
	Co-creation	Customers want to active join the new product development, which enables firms to create unique value for products. - DART (Dialogue, Access, Risk Assessment & Transparency) Model	Prahalad & Ramaswamy [64]
Direct Type (Customers convey their knowledge directly to engineers.)	Express processing (XP)	Starting from satisfying customers' basic needs, a methodology to improve products with frequent feedback from customers	Gassmann et al. [65]
	SCRUM	A holistic and flexible product development strategy for a team to achieve a common goal, similar with a rugby team	Takeuchi [66]

The product concepts with technological solutions and alternatives from developers should be tested iteratively through variety of channels like prototyping, narrative, or field tests until the establishment of clear concepts for product success [58], [67]. In this case, because communication between engineers and customers is proceeded indirectly, marketers as intermediators should try to minimize any types of distortions in delivering knowledge to each side. Of course, first of all, the strategy which project teams established at the very first step of the FFE should be considered in delivering knowledge. However, over-filtering or subjective interpretation by intermediators may lead to misunderstanding of the knowledge, which can produce poor or wrong results unintentionally. To prevent this, marketers need to understand the technological core competency of the firms. Simultaneously, engineers are also required to actively participate in analyzing customer knowledge which marketers brought from customers rather than accepting passively. Fundamentally, organizations can consider providing engineers with new ways which engineers can instantly or virtually test customer responses on the technological alternatives for a new product with.

B. Parallel Type of Knowledge Path

Next, with advancement of information and communication technology (ICT), engineers have been able to contact customers under collaboration with other discipline. In other words, engineers can obtain customer knowledge from or with other divisions and customers, and simultaneously transfer their technological alternatives on problems to other stakeholders in parallel.

Unlike other traditional market research methods, empathic design allows engineers to contact and interact with customers for knowledge generation and opportunity identification in the FFE [52], [60]. Based on empathy generated by observation and cooperation of customer participants, engineers can draw technological solutions for a target product. Also, the Internet has enlarged the opportunity engineers can gain the social aspects of customer knowledge [68]. In particular, Büyüközkan, Baykasoğlu and Dereli show how the Internet and web-based tools help project teams to communicate with customers for variety activities in the whole product development process [61], [62]. In addition, according to the "Lead Users" concept by Von Hippel, customers with deep understanding of their needs can provide information about market trend or innovative solutions to engineers [4], [63]. Lastly, going one step forward from the "Lead Users" concept, current customers participate in developing products by having continuous communication through various ways such as suggestion box, online communities, professional communities, or service providers [64].

In these communicational circumstances, engineers are required to have better communication skills such as translation, clarity, negotiation and listening as well as interpersonal skills like teamwork, group skills, attitude or work ethic [69], [70]. Particularly, unlike other types of knowledge path, because engineers should collaborate with other divisions and contact customers directly at the same time, it is necessary for engineers to use intuitive communication tools or processes to help each member understand and reach consensus more easily.

C. Direct Type of Knowledge Path

The last type of knowledge paths between engineers and customers connect engineers with customers directly without any interference from other disciplines. In software industry, software engineers often work with customers by meeting customers and getting feedbacks frequently under specific processes, so called agile methods, such as eXpress processing (XP) and SCRUM [40], [65], [66]. With these methodologies, engineering teams should immediately respond to feedback from customers, and provide prototypes after reflecting customer requirements. Thus, engineers need extremely superior communication skills and interpersonal skills rather than other methodologies.

Out of software industry, fast changing customer markets also lead R&D to consider continually customer contribution throughout the whole product development process. In particular, development contractors such as IDEO and Tribecraft, which provide a professional technical service to develop new products with different organizational structures and processes, show intensive processes similar with XP in developing a product with frequent and continual customer contacts compared to in-house developers [71]. However, other than software industry and specific development contractors, these methodologies face several challenges in order to be adopted in the FFE of other fields. One of the challenges is that these agile methods look after higher level of intense collaboration and communication between team members compared to the traditional product development environment [72]. Therefore, engineers need to be re-educated for new type of development environment to enhance communication and interpersonal skills.

In this section, the challenges and the limitations of methods which are typically used for communication between engineers and customers are pointed out. Based on these challenges and limitations, several requirements of tools to enhance the quality of knowledge exchange between engineers and customers are proposed in the next section.

V. REQUIREMENTS FOR CUSTOMER RESEARCH TOOLS

In capturing customer needs and creating customer values in the FFE, success of product development turns on how deeply engineers comprehend customers' knowledge. The Venn diagram of Figure 5 shows the relationships between knowledge of engineers (blue), marketers (red) and customers (green). Marketers function as the "go-between" between engineers and customers: they inform engineers about what the customer will accept and investigate questions that

emerge in engineering through customer research. Accordingly engineers and customers only share a small amount of knowledge directly (see left side of Figure 5). Moreover, a large amount of customer knowledge is tacit or latent, as indicated by the small shaded section in each figure that represents the explicit customer knowledge. FFE results can be improved through adequate customer research methods that explicate more knowledge and improve knowledge exchange, thus increasing marketer knowledge, as well as the overlap between engineering and customer knowledge (see right side of Figure 5). However, FFE methods can only achieve these results if they are well adapted to the challenges of new product development and fulfill several requirements.

First, the FFE tools for connecting engineers to customers should provide a holistic system-oriented view to engineers. With these tools, engineers can understand the whole system beyond superficial problems or alternatives which they can get ordinarily, so that essential technological solutions on the new product can be drawn with expanded and thoughtful view to enable access to tacit knowledge of customers [26], [73]. The next requirement of tools to enable engineers to capture customer needs and create customer value in the FFE is the availability of scenario simulation for various alternatives. Simulation of scenarios can provide future market opportunities and variety of results on product concept development and testing [26]. Lastly, to reduce uncertainty for engineers in the FFE, tools should reflect dynamic changes of customers' knowledge on the results [27]. As showed from a number of examples in the history such as from everyday objects to industrial scientific and medical equipment, customer desires and behaviors on products are rapidly changing. Therefore, tools used to gain customers' knowledge in the FFE should enable engineers to acquire and test any changes related to whatever that leads customers to purchase products. [32]

In addition to reducing the uncertainty of the FFE, resolving equivocality between engineers and other divisions or customers is critical for the change of knowledge exchange in the FFE. In order to resolve equivocality, tools for knowledge exchange between engineers and customers should include three requirements; interactivity, interchange of subjective interpretation and support to establish organizational interpretation. First of all, several researches have proven that frequent, effective and mutual communication between two different groups is considered the best way to resolve knowledge conflict in several researches [8], [28], [74], [75]. Therefore, interactive communication tools will be supportive of better communication between engineers and customers. Also, the in equivocality issue, different subjective interpretations in each individual mainly cause conflicts and miscommunication between different parties [29], [41]. These different interpretations should be matched through knowledge exchange system or tools for the success of the FFE. Finally, tools for knowledge exchange tools should be helpful in drawing organizational conclusion in the FFE. With various interpretations from variety of information sources, project teams or firms should make concrete decision for the product success.

Based on six requirements explained above, each typical methodology described in the former section can be evaluated to investigate which methodologies have better capability for or what are the limitations of each methodology in the knowledge exchange between engineers and customers as shown in Table 3. Engineers can process the information gathered from various sources and multifunctional areas by using all methodologies. Most methodologies are designed to collect and translate the information to create and discover hidden needs or solutions in different ways. For example, using ATC, engineers can find optimal design values for desired specification established by conjoint analysis conducted with marketing people [9]. Also, in drawing organizational interpretation, all methodologies can be applicable because these provide systematic approaches to NPD teams or firms in making a decision on the NPD. However, most of need focused methodologies such as ATC, QFD, TRIZ, internal brainstorming and empathic design are difficult to reflect dynamic customer knowledge, to support interactive communication and to help exchange of subjective interpretations. It is because customer knowledge generally collected and transferred unidirectionally from the contact points, such as marketing and sales divisions, between firms and customers. In addition, the frequent update of customer knowledge needs not a few additional resources in using the need focused methodologies. However, in the case of

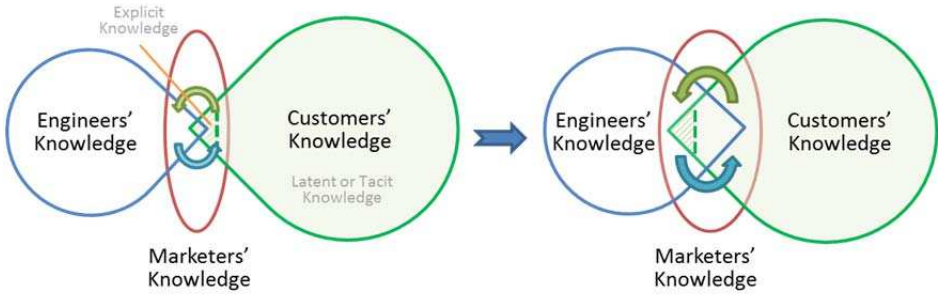

Figure 5. Knowledge Interchange between Engineers and Customers

TABLE 3. AVAILABILITY OF EACH METHODOLOGY FOR ENGINEERS TO CAPTURE CUSTOMERS' KNOWLEDGE

Knowledge Path Type	Methods	Information Processing	Simulation of Scenarios	Reflection of Dynamic Customer Knowledge	Interactive Communication	Exchange of Subjective Interpretation	Drawing organizational Interpretation	Need /Solution Focused
Serial Type	Analytical Target Cascading (ATC)	Available	Unavailable	Unavailable	Unavailable	Unavailable	Available	Need Focused
	Quality Function Deployment (QFD)	Available	Unavailable	Unavailable	Unavailable	Unavailable	Available	
	TRIZ	Available	Unavailable	Unavailable	Unavailable	Unavailable	Available	
	Internal Brainstorming	Available	Unavailable	Unavailable	Unavailable	Unavailable	Available	
Parallel Type	Empathic Design	Available	Unavailable	Unavailable	Limited	Available	Available	Solution Focused
	Web-based interactive	Available	Unavailable	Limited	Available	Available	Available	
	Lead Users	Available	Unavailable	Available	Available	Available	Available	
	Co-creation	Available	Unavailable	Available	Available	Available	Available	
Direct Type	Express processing (XP)	Available	Unavailable	Available	Available	Available	Available	
	SCRUM	Available	Unavailable	Available	Available	Available	Available	

empathic design, engineers can share the results of their observation with and get feedback from the customers who joined the process. Nevertheless, empathic design also needs additional resources such as time and cost. On the other hand, most of the solution focused methodologies, such as web-based interactive, lead users, co-creation, XP and SCRUM, ask for spontaneous participation of customers basically. Therefore, these solution focused methodologies are available to reflect dynamic customer knowledge, interactive communication and subjective interpretation exchange. Lastly, as shown in Table 3, there is no available method for simulation of various scenarios. However, simulation of scenarios is an important requirement for knowledge exchange between engineers and customers in assuring the success of product development and identifying future market opportunities, product concept development and testing [26].

VI. DISCUSSION

For the success of product development, recent product development processes tend to involve customers aggressively in the FFE. However, according to Enkel, Kaysch and Gassmann, there are considerable inherent risks of customer integration on the product development; loss of know-how, dependence on customers, limitation to mere incremental innovations, serving only niche markets and misunderstanding between customers and employees [52]. In particular, these inherent risks may restrict knowledge exchange between engineers and customers unless tools or processes provide proper risk management elements for the FFE. Therefore, to prevent these risks, organizations or project teams need to be well-acquainted with characteristics of each tool for knowledge exchange between engineers and customers, and provide institutional frameworks such as IP management, staff management and incentive system [52].

Particularly, as mentioned above, customer integration has a risk which limits product development to incremental innovation rather than radical innovation. To develop radical innovation for products, firms or project teams need to have capability to involve the right customers at the right time in the right form [37], [76]. Also, in involving customers for a product development project, organizations are required to establish a clear product strategy, a well-planned portfolio of new products and an organizational structure supportive of the FFE activities at the very initial stage in the FFE [13].

Moreover, some of methodologies such as QFD and empathic design need huge amount of resource like time, staffs and cost [55]. But, most of firms which do not have enough resources still hesitate to invest huge resource for fuzzy and unclear development project in initial stage even though they recognized the importance of the FFE. Therefore, to respond to the six requirements for knowledge exchange between engineers and customers, new type of tools are required to be easy to use and intuitive for both engineers and customers in exchanging their mental model.

VII. CONCLUSION

Focusing on uncertainties and equivocality between engineers and customers in the FFE activities, this study investigated proper requirements of methodologies to capture customer knowledge from the viewpoint of engineers as members of project teams for new product development. Specially, this investigation was developed from that customer involvement have been suggested one of the critical solutions to resolve uncertainty and equivocality through literature review, and that there is the existence of various communicational distortions between engineers and other members of NPD teams or customers in the FFE. Therefore, methodologies for collaboration between engineers and customers in the FFE are required to minimize communicational distortion which may occur in knowledge exchange between engineers and customers, to enable access to customers' latent and tacit experiences, and to help engineers in obtaining optimal solutions for the product success. For these ideal methodologies, six requirements should be secured; information processing, simulation of scenario, reflection of dynamic customer knowledge change, interactive communication, exchange of subjective interpretation and drawing organizational interpretation. Figure 6 summarizes schematically that the size of knowledge sharing area between engineers and customers can expand by the developed methodological requirements in this study.

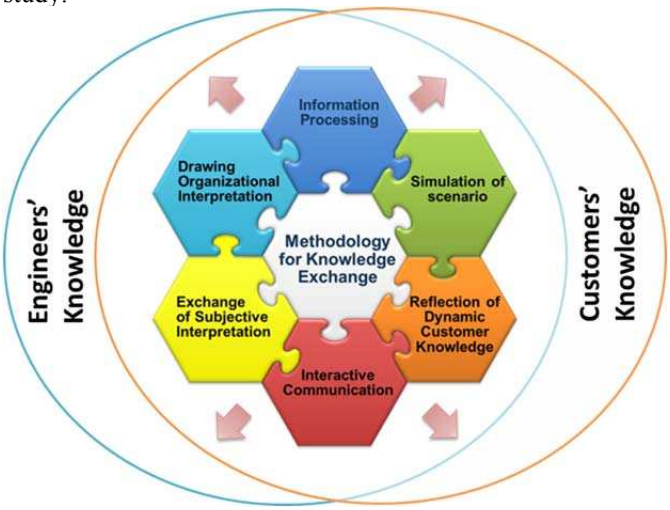

Figure 6. Methodological Requirements for Knowledge Exchange between Engineers and Customers

When typical ten methodologies for customer involvement activities or capturing customer knowledge are evaluated, simulation of scenario is hardly dealt with by any methodologies. In addition, some methodologies require additional help or education for engineers and have difficulties with being diffused throughout general fields from specific industries.

Therefore, considering tools to connect engineers with customers for the successful FFE, project teams need to look

for optimal alternatives which can make up for these problems. Also, in the near future, a new frame work can be established for engineers to capture customer knowledge and create better customer value with customers in the technology-driven FFE environment.

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